SURVEY OF FORD MOTOR COMPANY DISCHARGE AT OAKVILLE, LAKE ONTARIO, 1984

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1.0 CONCLUSIONS

1. The Ford Motor Company of Canada discharges biochemical oxygen demand (BOD) to Lake Ontario at an average concentration of 22.5 mg/L, 50% higher than the Ministry industrial effluent guideline concentration of 15 mg/L. The resultant average daily BOD loading is 310 kg/day. Effluent concentrations of other parameters (total phosphorus, phenolics and solvent extractables) are within their objective values.

2. PCBs and organochlorine pesticides are below detection limits in the effluent.

3. In the nearshore Lake Ontario area, concentrations of all heavy metals measured are in compliance with Provincial Water Quality Objectives, except for exceedences for copper and nickel observed in the immediate vicinity of the outfall on three and two of the five sampling days, respectively.

4. Total phosphorus concentrations in the plume exceeded the Ministry guideline of 0.02 mg/L for prevention of nuisance algae growth at distances of at least 0.5 km from the outfall in the direction of the current.

5. Dissolved oxygen concentration in the vicinity of the outfall tended to be slightly below saturation, but in no cases was severe dissolved oxygen depletion observed. This is attributed to the dynamics of the nearshore lake area.

6. Dye and drogue tracking studies indicated that the zone for 80% effluent dilution (dilution of the effluent concentration to 20% of its initial value) extended about 200 to 300m northeast of the outfall parallel to shore. Chemical analysis of water samples taken in the plume indicated a similar or slightly greater distance for 80% dilution.

7. Currents in the vicinity of the outfall averaged 2 to 3 cm/s, either parallel to shore towards the northeast, or onshore towards the north or northeast. Average speeds were lower than those observed during long-term current meter studies at Lakeview, about 15 km northeast of the study site; currents towards the southeast observed at Lakeview, were not seen here. These differences may have been due to the short-term nature of the present study.

8. Although considerable variability was observed both in space and time, the magnitude of dispersion was similar to that observed at Lakeview.

9. Analysis of samples from streams and storm sewers in the area indicated intermittent high concentrations of nutrients and BOD at the Cox Drive storm sewer; otherwise no unusually high results were observed. However, no noticeable impact of this storm sewer on the nearshore area was observed.

2.0 RECOMMENDATIONS

1. The Ford Motor Company of Canada should complete its planned diversion of its effluent to the Town of Oakville sanitary sewage system as soon as possible.

2. The Ford Motor Company of Canada should be directed to reduce discharges of phosphorus and heavy metals such as copper and nickel in order to reduce the frequency of objective exceedences near the outfall at present. In the event of diversion of their effluents to the sanitary sewage system, such treatment at source will be beneficial in minimizing impacts of heavy metals on the STP.

3. If the planned diversion does not take place, the Ford Motor Company of Canada should be directed to reduce its effluent biochemical oxygen demand concentration to the Ministry industrial effluent objective value of 15 mg/L.

3.0 INTRODUCTION

The Ford Motor Company of Canada plant, an automobile and truck manufacturing facility in Oakville (Figure 1), draws process water from an intake situated 1 km from shore in nearby Lake Ontario, and discharges it, along with several waste streams, to the lake through an outfall located 0.2 km from shore in a semi-confined area. About 3 km northeast of the outfall is located the Canada Cement Co. wharf, which extends several hundred metres into the lake and introduces a potential for alteration of current regimes.

Various process waste streams within the plant are pretreated with sulphuric acid, caustic and ferric chloride, and discharged to two lagoons, where most of the contaminants are settled out. Effluent from these lagoons, together with that from a small STP which treats plant sanitary wastes, is diluted by relatively clean cooling water and discharged at an average rate of 12,100 m^3/d (2.7 MGD) to the lake. Ford's discharge to Lake Ontario is authorized by a Certificate of Approval issued in August 1969 by the Ministry (at that time, the Ontario Water Resources Commission). Although objectives are not numerically specified in the Certificate, it does contain the condition that the effluent discharged to Lake Ontario is to comply with Ministry objectives as they apply to waste water discharged to storm sewers or natural water courses.

In recent years, effluent concentrations of total P, total suspended solids, phenolics and solvent extractables have been in compliance with Ministry objectives (Table 1). However, BOD loadings have consistently exceeded objective values, with effluent concentrations averaging 25 mg/L, and monthly (1983) values as high as 36 mg/L. Concern has been expressed that localized dissolved oxygen depletion could occur because of the BOD concentration and the semi-enclosed nature of the area surrounding the outfall.

The discharge pipe extends about 250m from shore with the outfall approximately 2.5m deep in a total water depth of 4m. The shoreline in the immediate vicinity consists of mainly suburban residential area, with several storm sewer outfalls and small creeks emptying into the lake in the area (Figure 2).

Nearshore currents in the area are generally from southwest with periods of northeast occurring at times, particularly during the winter (Pickett and Bermick, 1977; Pickett, 1977). Current meters were operated at Lakeview on a similar stretch of Lake Ontario shoreline about 15 km northeast of Oakville during 1983-84 (MOE, unpublished data). These data showed the currents to have a bimodal distribution, with northeastward and southwestward currents occurring similar portions of time, with monthly average current speeds of 4 to 10 cm/s. Highest average speeds were in the late fall to early winter (November-January).

The lagoon sludge is known to be highly contaminated with heavy metals originating from the industrial processes (Table 2). Traces of organic contaminants were also found in the sludge; these included 7 ug/g of PCBs, 1380 ug/g of two xylene isomers, and 0.1-1.0 ug/g of two other substances, tentatively identified as hexachlorobenzene and aldrin. Thus, the process effluent with its suspended material load is a potential source of trace contaminants to the lake.

This study was conducted in 1984 at the request of the Oakville District Office of the Ministry, to determine the effect, if any, of the excessive BOD discharge to the nearshore lake area. It was also decided to determine the extent of impact of other substances from the outfall on the nearshore lake area. Technology for tracking small effluent plumes in the nearshore area using dye and drogues is also discussed.

4.0 STUDY METHODOLOGY

The field study involved plume tracking using dye and drogue clusters, and water sampling at the effluent in the plume, and at nearby streams and storm sewer outfalls. From the plume tracking results, dilution envelopes were calculated, and compared to the results of the water chemistry samples taken to verify the observed dilutions.

The plume tracking procedures were conducted under contract by Gore and Storrie Ltd. The field and data analysis procedures are summarized below; further details are contained in their report (Gore and Storrie, 1985).

4.1 Field Procedures

4.1.1 Dye Release Studies

Rhodamine dye (50 to 100 ml) was mixed with 5-6 times as much lake water in a bottle, so that its density was similar to the lake water. The dye mixture was released with the outfall at the shoreline manhole and the time of release, as well as the time of first dye appearance at the end of pipe, was noted. At several times over approximately 3 to 4h, the resulting plume was traversed in two orthogonal directions by a small boat travelling at constant speed, and the dye concentration profiles were measured with a recording fluorometer. From the dye concentration profile the dispersion coefficient and dilution were calculated as described in Appendix 2, and the centroid of the plume (center of mass) was used to define the mean path of the dye release.

4.1.2 Drogue Release Studies

Four sail drogues (described in Gore and Storrie, 1985) were released directly above the end of pipe, which was visible as the point where the dye plume surfaced. On days in which no dye was used, turbulence and the appearance of suspended material indicated the point at which the plume surfaces; had this not been visible, a small amount of dye could have been used to locate it. The drogues were tracked for up to 6h. At various times, the drogue positions were located using Loran C. or radar fixes. As with the dye studies, the centroid (average latitude and longitude of the 4 drogues) represented the average plume track, and the spread between the drogues represented the variance which was used to calculate dispersion and dilution as described in Appendix 2.

4.1.3 Water Samples

Triplicate samples of effluent were collected at the manhole on each survey day prior to dye release. Samples were also collected at Morrison and Wedgewood Creeks, and storm sewers at the foot of Maple Grove, Cox and Arbor Drives (Figure 2). The purpose of the stream and storm sewer samples was to detect the input of any contaminant to the survey area originating from a location other than the Ford outfall.

During the plume tracking, water samples were collected at the intake and outfall (end of pipe; Figure 2), and a series of samples was collected from the plume as defined by the drogues. Profiles were also taken at the lake locations for temperature, dissolved oxygen and conductivity. All samples were analyzed for nutrients and BOD; PCB-pesticides, heavy metals, phenols and solvent extractables were determined on the triplicate effluent samples, the end of pipe lake sample and the intake sample only. The intake sample was considered as "background" concentrations for purposes of comparing observed and calculated dilutions.

5.0 RESULTS AND DISCUSSION

Five days' worth of data were obtained, including drogue tracking and water samples on all days and dye studies on the first two days. The entire survey was originally scheduled for the week of September 17, 1984, but due to plant shut-down on September 18, the final three days were re-scheduled for the week of October 23. Dispersion and dilution results obtained by Gore and Storrie (1985) are first examined; these results are then applied to the water samples obtained by the Great Lakes Section.

5.1 Dispersion and Dilution

Details of results obtained on individual days, including tables of variance data and daily drogue tracks are given by Gore and Storrie (1985) and are briefly summarized here. A sample dye plume is given in Figures 3 and 4, and a sample drogue track is shown in Figure 5. Figure 6 shows the locations of leaks in the submerged outfall pipe as shown by the dye releases. Qualitatively, the volume of "leaked" effluent was small compared to that which reached the end of pipe, as shown by the relative sizes of the dye patches. It was not possible to prove any deleterious effect of these leaks on the nearshore water quality.

5.1.1 Currents

A summary of wind and current conditions is given in Table 3. At no time during the study did the drogues move in an offshore direction. The winds during the study were predominantly from the SE (onshore) to SW or W (approximately parallel to shore). Currents were predominantly parallel to shore towards the NE, or on-shore in a N-NW direction, with average magnitudes of 2 to 3 cm/s. The surface drogue on September 17 moved much more rapidly (9 cm/s), apparently being affected by surface-layer currents. As this was not representative of plume conditions, it was not considered in the dispersion analysis.

Average current speeds observed in this study are lower than those observed during current meter studies at Lakeview (MOE, unpublished data) (4 to 10 cm/s), and also during drogue tracking in the same area (Gore and Storrie, 1984). In both these studies, alongshore currents were observed towards the southwest, as well as the northeasterly direction found here. These differences may be the result of the very limited data set obtained during this study; longer-term average currents in the vicinity of the Ford outfall may be expected to show characteristics somewhat similar to those of Lakeview.

5.1.2 Dispersion

The variance for the dye and drogue runs, calculated as described in Appendix 2, was plotted against the elapsed time in Figure 7, in order to estimate an average range of dispersion coefficients and its growth with time. Linear regression results for the various runs are summarized in Table 4. It can be seen that the growth rate of variance with time varies between the powers of 1 and 3 on different days, although the correlation coefficients (r^2) indicate a good degree of constancy with time within any given run. These represent the expected ranges of growth rates as summarized by Murthy and Miners (1978), who found growth rates of powers of 2.3 to 2.8 from some dye studies in Lake Ontario.

If all the data are pooled together, a growth rate to the power 1.22 results; however the scatter is very large and the "high growth rate" results (September 18 drogues; October 23-24) are obscured. Nevertheless, this mean growth rate is indistinguishable from that (1.127) observed during similar studies at Lakeview (Gore and Storrie, 1984). The magnitude of the variance (10^2 - 10^4 m^2) is also similar to that observed at Lakeview and in other nearshore studies (e.g. Palmer, 1977). The results of Murthy and Miners (1978), on the other hand, showed growth rates of powers similar to the "high growth rate" results obtained here (power of 2.8). Their experiments were conducted over longer time periods (10^4 - 2 x 10^5 s), and obtained a variance of approximately 10^4 m^2 at 10^4 s. The data obtained in this and other studies show that dispersion is a phenomenon with considerable variability both in space and time. This fact of necessity limits the accuracy of the dilution envelopes.

5.1.3 Dilution

The dilution envelopes are developed from the variance and velocity data, knowing that the dilution is inversely related to variance and velocity. For the various runs, the dilution ratio as a function of distance from the point of release is calculated as outlined in Appendix 2. Variance at any given time is given by the equations in Table 4, and mean velocities are given in Table 3. Figure 8 gives the resulting dilution ratios vs. distance. These dilution ratios can be used along with the mean direction of travel to estimate dilution contours about the source for any desired dilution level, for example 5:1 as shown in Figure 9. In this figure, the range of measured mean velocities in Table 3 has been used to estimate mean and minimum dilution envelopes.

The dilution envelopes are skewed towards the northeast. It is suggested (Gore and Storrie, 1985) that this result is due to the small amount of data (1 day) available for currents towards the southwest. The lack of data in the offshore to southwest directions is indicated by the dashed lines in Figure 9. The envelopes for the northeast direction are probably more typical of expected dilution ratios and should probably be used for both directions in the absence of additional data for the southwest direction. Such a more symmetical dilution envelope was observed at Lakeview (Gore and Storrie, 1984), for which a wider range of current directions was obtained.

5.2 Water Chemistry

Results of triplicate daily effluent samples taken at the shoreline manhole are summarized in Table 5, and results of daily samples taken from the lake adjacent to the outfall and intake buoys are summarized in Table 6. The observed mean loadings in Table 5 were calculated from the average daily flow over the five survey days (13.9×10^3 m^3/d) based upon daily flow data supplied to the Ministry by Ford. This flow rate is slightly higher than the value (12.1×10^3 m^3/d) used for estimating the maximum allowable loadings. Detailed raw data, including results of samples taken from adjacent storm sewers and mouths of creeks, are given in Appendix 1. All locations referred to are shown in Figure 2.

In Table 5, loadings are compared to the maximum allowable loadings; in addition the observed concentrations are compared to the industrial effluent objectives where available. It is found that, except for BOD, all parameters are within the Ministry's industrial effluent objectives. However, the average BOD load of 310 kg/d is about 70% higher than the maximum allowable load (182 kg/d); the average BOD concentration is 50% higher than the industrial effluent objective. However, daily results (Appendix 1) show considerable variability with daily average BOD concentrations ranging from 2 to 46 mg/L.

It is expected that more specific objectives for heavy metals will be introduced under the Municipal-Industrial Strategy for Abatement (MISA) technology-based approach (Best Available Technology Economically Achievable - BAT; MOE, 1986b).

In addition to the parameters shown in Table 5, the PCB-organochlorine pesticide scan was done on each effluent sample; all results were below detection limits. It should be noted that this scan also includes hexachlorobenzene, despite the fact that this compound is actually an industrial organic chemical.

In Table 6, the lake water quality in the vicinity of the outfall and intake are compared with each other and with Provincial Water Quality Objectives, where applicable. Local exceedences of objectives are observed at the outfall site for total phosphorus (guideline), and part of the time for copper and nickel (although the average for nickel was just below objective, 2 of the 5 individual samples exceeded the objective - see Appendix 1). Based upon approximate dilution contours (Figure 9), it can be expected that these metals will generally be within objective levels at a distance of approximately 300m from the outfall in the along-shore direction. At the intake site, all parameters measured were within objectives. Except for turbidity, averages were similar to those observed at background locations in other recent western Lake Ontario studies (Griffiths, 1983; Poulton and Griffiths, 1986; MOE, 1986). Turbidity was highly variable and may have originated as much from nearshore sediment resuspension and erosion, as from the outfall itself.

Representative profiles of dissolved oxygen and temperature near the outfall and at two plume locations are shown in Figure 10. Average dissolved oxygen values of about 10 mg/L represent about 90 to 100% saturation at water temperatures of 12 to 13°C observed during the October portion of the survey. Minor D.O. depletion (D.O. about 9 mg/L or 85% saturation) frequently occurred at the surface at the outfall location (Figure 10a). At no times was severe oxygen depletion observed nor was there any significant depletion of dissolved oxygen with depth. The lack of depth dependence is to be expected, considering the shallow water depth (< 7m) and accompanying lack of thermal stratification during the survey period.

Water quality of storm sewers and stream mouths in the vicinity of the outfall (Figure 2) was measured to indicate whether or not any extraneous sources might exist which would contribute to the plume. Average results are shown in Table 7 and individual results in Appendix 1. As no flow data were measured, the results are only qualitative; however, it appears no influence of these locations should occur except possibly for the Cox Drive storm sewer on September 18 and October 23, on which dates considerable elevation of most parameters was observed (see Appendix 2 and Table 7). The reason for these elevated results is not known. As surveys were undertaken during dry weather, these do not indicate a runoff effect. At any rate, the flow rate is expected to be quite low and the distance of this sewer from the outfall is large enough that no influence on the plumes was observed. However, the reason for these elevations should be investigated.

5.2.1 Plume Chemistry

Dilution of the effluent can be considered to occur in two stages: initial (near field) dilution at the end of the effluent pipe and far field dilution in the plume itself. Estimates of these processes were made from water chemistry results from the vicinity of the outfall pipe and the plume, respectively. Dilution as measured by dye and drogue tracking (Section 5.1.3) is assumed to represent far-field dilution, and the dilution envelope (Figure 9) is compared accordingly.

Initial dilution was calculated from the effluent, outfall and intake data (Tables 5, 6 and Appendix 1) as follows:

$$\text{Dilution} = \frac{[\text{outfall}] - [\text{intake}]}{[\text{effluent at shore}] - [\text{intake}]}$$

where square brackets represent concentrations at the indicated locations and the intake location is assumed to represent lake background conditions. Average initial dilutions for the 5 survey days were 0.167, 0.133, 0.181, 0.303, 0.230 and 0.111 for total Kjeldahl N, total P, conductivity, Cu, Ni and BOD, respectively, suggesting dilution ratios of 1:3 to 1:10 in the vicinity of the end of pipe. However, daily values varied considerably, also as in-lake concentrations can vary rapidly with distance near the end of pipe (see discussion of far-field dilutions on October 25), these numbers probably overestimate the initial dilution ratio. At any rate, the initial dilutions are less than those (1:10 to 1:20) expected for a well-constructed diffuser outfall.

Far-field dilution from the outfall pipe to various water chemistry sample locations in the plume was considered in a similar manner for the above parameters. Conductivity was not used as differences between various locations were generally small.

As should be expected, the most significant differences were observed with BOD. Figures 11a-c show BOD results for the plume, intake and outfall on the October survey dates, compared with the dilution envelopes (Figure 9). The network of closely-spaced samples on October 25 (Figure 11c) showed a large variation within a hundred metres of the outfall with the largest values slightly onshore of the outfall in the direction of water movement (Table 3). It is evident that observed concentrations are being affected by incomplete mixing of the effluent with the lake water over short distance scales; such a result is not unusual and indeed is observed in the irregular nature of the dye concentration profile observed in this study and others in the nearshore area (Figure 3; Gore and Storrie, 1984, 1985).

Consequently, the concentrations observed near the outfall on any sampling date are not necessarily the maximum initial near-field concentrations and estimated dilutions from this value can be regarded as only approximate.

On October 23, dilution was very similar to that predicted (Figure 11a), while on October 24, apparently less dilution was occuring (Figure 11b; plume concentrations greater than the 80% dilution value appear well to the northeast). This could be because of either the sub-grid scale variation of initial dilutions mentioned above, or less far-field dilution. The data obtained are not adequate to assess this further.

Figures 12a-c show plume total phosphorus results for the October dates. As with BOD, more dilution was observed on October 23 than on October 24, and the maximum October 25 concentration was about 60m northwest of the outfall. However, overall dilution values on all dates were slightly higher than for BOD (i.e. concentrations approached background faster). This suggests more rapid assimilation or sedimentation of phosphorus compared to BOD. Nevertheless, all samples within the plume showed total P concentration above the guideline (0.02 mg/L) for prevention of nuisance algae growth. Thus the area with total P concentration above the guideline extends at least 0.5 km from the outfall in the direction of the current.

Dilution of total kjeldahl nitrogen with distance from the outfall was similar to that of BOD and is not further discussed.

Overall the plume results show that the suggested dilution envelopes are a reasonable estimate of far-field dilution within the approximations involved in their estimation and considering the variability of initial dilution near the outfall pipe.

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TABLE 1

Summary of Wastewater Loadings

Ford Plant, 1984

Parameter	Load (Kg/day)	Maximum Loading Requirement (Kg/day)	Industrial Effluent Objective Concentration (mg/L)
Total Phosphorus	4.65	12.1	1.0
BOD	345	182	15
Suspended Solids	154	182	15
Solvent extractables	23	182	15
Phenolics	0.099	0.24	0.020

Note: Above data from MOE Industrial Monitoring Information System, Wastewater Discharge Summary, 1984.

Loads are based upon an average effluent flow of 12,100 m^3/d.

TABLE 2

Analysis of Lagoon Sludge

Ford Plant, 1983

Parameter	Concentration
Oil and Grease (Hexane Soluble)	16900 mg/Kg
Phenol	4.1 "
Loss on Ignition @ 600°C	34.2%
COD	193000 mg/Kg
Total Cadmium Cd	6 "
Total Chromium Cr	3550 "
Total Copper Cu	110 "
Total Iron Fe	36600 "
Total Nickel Ni	6100 "
Total Zinc Zn	10800 "
Xylenes	1380 ug/g
PCB	7 "
Unknown substances (tentatively identified as hexachlorobenzene and aldrin)	0.1 - 1.0 ug/g

Data collected by Enviroclean Ltd., London, Ont. for Ford.

TABLE 3

Summary of Dye and Drogue Trackings

Ford Plant, 1984

Date	Type	Wind Direction (from)	Wind Speed Km/h	Average Current Speed cm/s	Current Direction (to)
Sep. 17	Dye	SE-onshore	2.5-3.7	4.4	NE-parallel to shore
	Surface	SE-onshore	2.5	11.2	NE-parallel to shore to onshore
	Sail	SE-onshore	2.5-3.7	3.3	NE-parallel to shore
Sep. 18	Dye	SE-onshore	1.9	1.1	W-onshore
	Sail #1	SW-parallel to shore	1.9	2.6	SW-parallel to shore
	Sail #2	SE-onshore	3.1	1.4	NW-onshore
Oct. 23	Sail	W-parallel to shore	1.2-2.5	3.4	NE-parallel to shore
Oct. 24	Sail	Variable	1.2-3.7	3.2	NE-parallel to shore
Oct. 25	Sail #1	SW-S-onshore	1.2-2.5	1.3	NW-onshore
	Sail #2	S-onshore	2.5-6.2	2.0	N-onshore

TABLE 4

Equations for Variance vs. Time Plot

Using Relevant Trackings

Date	$y = at^b$	r^2
Sept. 17		
Dye	$\sigma^2 = 0.898t^{0.93}$	0.954
Sails	$\sigma^2 = 0.207t^{0.94}$	0.663
Sept. 18		
Sails	$\sigma^2 = 2.703\times10^{-8}t^{2.7}$	0.993
Dye	$\sigma^2 = 0.4069t^{0.90}$	0.495
Oct. 23		
Sails	$\sigma^2 = 1.008\times10^{-5}t^{2.24}$	0.963
Oct. 24		
Sails	$\sigma^2 = 3.375\times10^{-11}t^{3.37}$	0.995
Oct. 25		
Sails	$\sigma^2 = 0.018t^{1.45}$	0.995
Sails	$\sigma^2 = 0.0008t^{1.65}$	0.990
Grouped Data Fitting		
All data	$\sigma^2 = 0.032t^{1.22}$	0.429
"High growth rate" (Sep. 18 Sails, Oct. 23, 24)	$\sigma^2 = 1.57\times10^{-8}t^{1.282}$	0.577

t = Elapsed time from Release of Drogues

TABLE 5

Water Quality of Ford Effluent, as measured at shoreline manhole, Sept. - Oct. 1984

Parameter	Loading (kg/day)		Concentration (mg/L)	
	Maximum Allowable Requirement	Observed Mean	Observed Mean	S.D.
Total P	12.1	7.1	0.51	0.18
BOD	182	310	22.5	18.9
Phenolics, ug/L	0.24	0.056	4.1	3.1
Solvent Extractables	182	25	1.8	1.1
NH_3-N	-	2.6	0.19	0.18
Total Kjeldahl N	-	16.9	1.22	0.29
Conductivity, umho/cm	-	4200*	463	49
Turbidity, FTU	-	-	12	17
Cd	-	-	<0.0002	-
Cu	-	0.5	0.035	0.006
Cr	-	0.8	0.12	0.009
Fe (12 samples)	-	2.1	0.189	0.094
Ni	-	1.3	0.097	0.056
Pb	-	0.1	0.006	0.003
Zn	-	0.9	0.063	0.036

NOTE: All concentrations are in mg/L unless otherwise noted.
All results are means of 15 samples (3 per day), unless otherwise noted.
*Total dissolved solids loading (calculated from conductivity x 0.65).

TABLE 6

Water Quality of Lake Ontario, as measured at Ford Oakville outfall and intake buoys, September - October 1984

	Outfall		Intake		PWQO
	Mean	SD	Mean	SD	
NH_3-N	0.09	0.09	0.05	0.01	**
Total Kjeldahl N	0.44	0.09	0.28	0.02	-
Total P	0.081	0.050	0.014	0.002	0.02*
Conductivity, umho/cm	346	27	321	3	-
Turbidity, FTU	9.7	18.6	2.0	1.0	-
BOD	3.1	2.7	0.7	0.2	-
Cd	<0.0002	-	<0.0002	-	0.0002
Cu	0.012	0.009	0.002	0.001	0.005
Cr	0.011	0.012	0.003	0.0	0.1
Fe	0.036	0.012	0.024	0.025	0.3
Ni	0.022	0.024	0.001	0.0	0.025
Pb	<0.003	-	<0.003	-	0.025
Zn	0.016	0.014	0.002	0.001	0.030
Phenolics, ug/L	<1	-	<1	-	1
Solvent Extractables	<1	-	<1	-	-

Note: All results are in mg/L unless otherwise noted.
All results are means of 5 samples, one per survey day.
* Guideline for prevention of nuisance algae growth.
** 0.02 mg/L as unionized NH_3; pH was not measured on this survey.

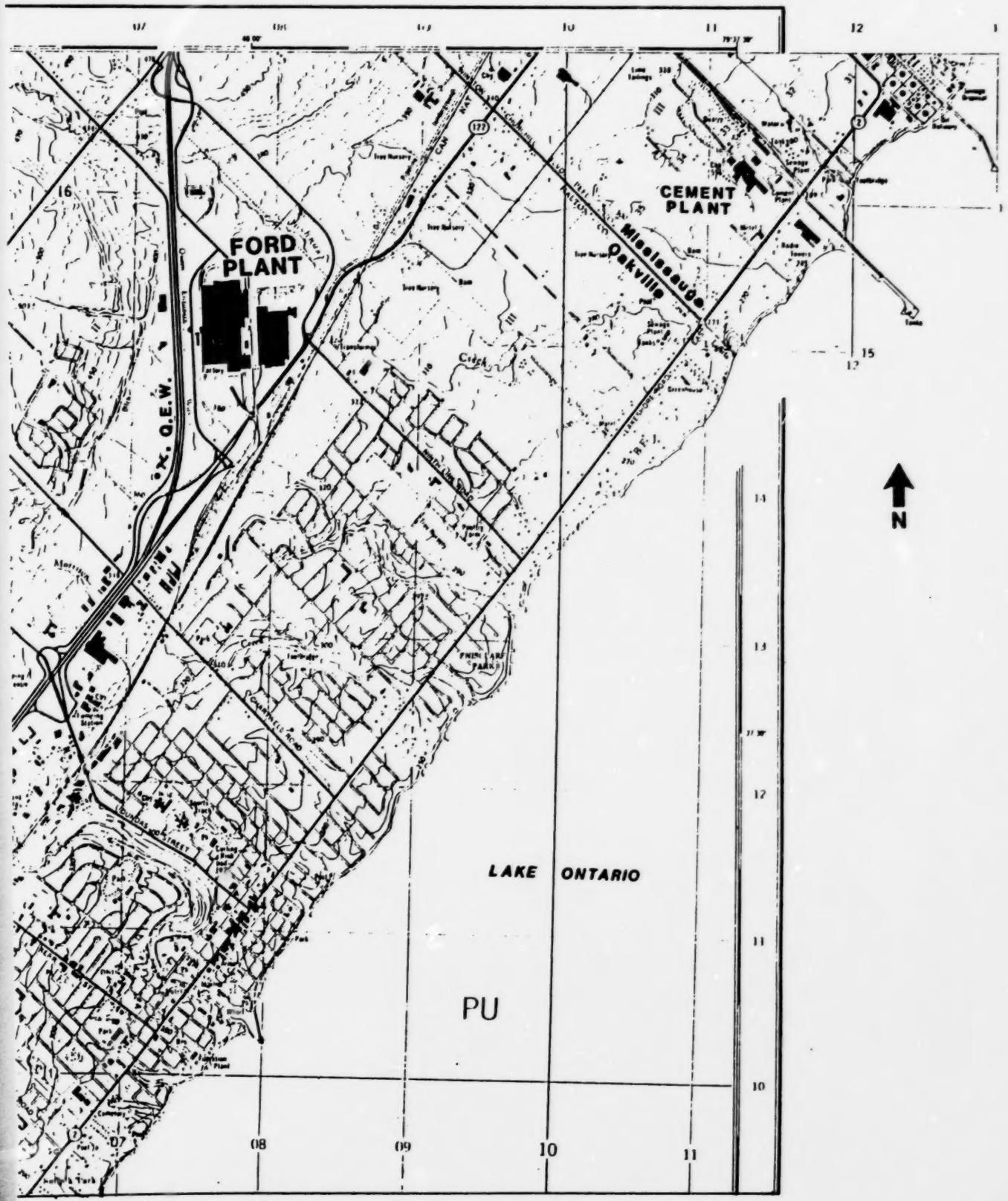
TABLE 7
Water Quality of Streams and Storm Sewers in Vicinity of
Ford Oakville, 1984

	Arbor Dr. Storm Sewer		Maplegrove Dr. Storm Sewer		Wedgewood Creek		Cox Dr. Storm Sewer			Morrison Creek	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Max**	Mean	SD
NH_3-N	0.023	0.024	0.012	0.007	0.014	0.008	0.13 0.022*	0.15	0.34	0.029	0.015
Total Kjeldahl N	0.47	0.48	0.26	0.04	0.40	0.09	2.0 0.37*	2.9	7.1	0.44	0.20
Total Phosphorus	0.018	0.007	0.023	0.009	0.036	0.015	1.8 0.47*	2.6	6.4	0.036	0.008
Conductivity umho/cm	744	91	1084	9	827	247	957	80	-	683	103
Turbidity FTU	1.3	0.7	1.9	1.4	4.0	1.9	16 0.50*	27	64	3.6	1.3
BOD	0.22	0.12	0.50	0.46	0.64	0.40	21 0.37*	39	90.4	0.60	0.34

Note: Values in mg/L unless otherwise indicated.
* Average values excluding results of September 18 and October 23.
** Maximum values (October 23).

FIGURE 1

GENERAL AREA OF FORD PLANT



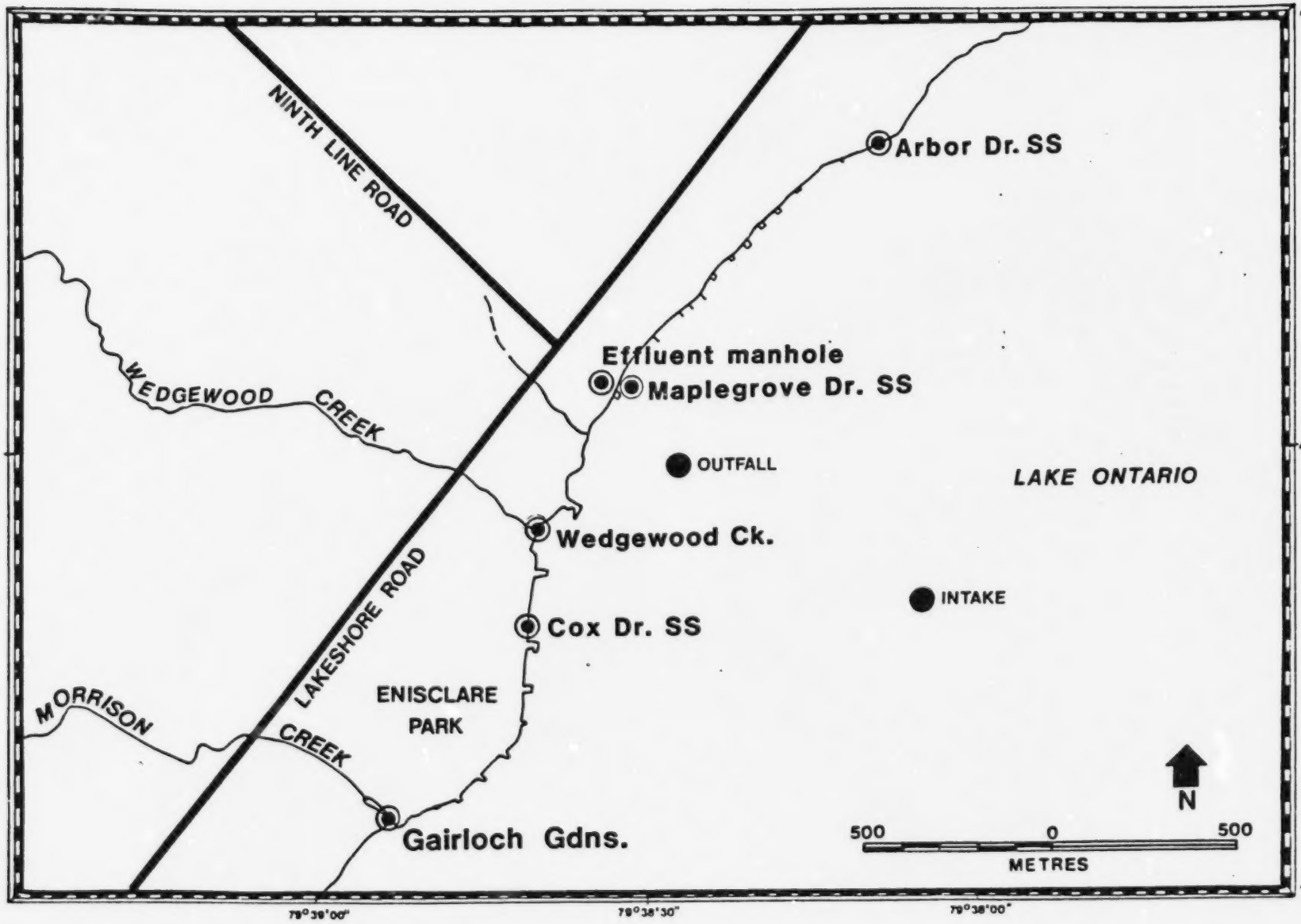
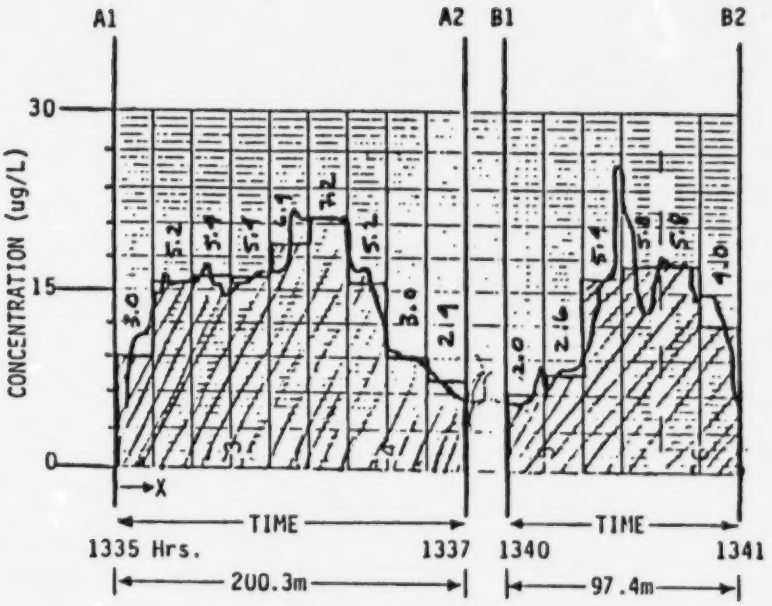


FIGURE 2
FORD-OAKVILLE SAMPLING LOCATIONS

FIGURE 3

ANALYSIS OF A TYPICAL DYE PLUME
(September 18, 1984)



A1 = 43°28'06.3"
79°38'34.6"

A2 = 43°27'59.8"
79°38'34.6"

Real Distance = 200.3 m

B1 = 43°28'04.2"
79°38'35.7"

B2 = 43°28'03.7"
79°38'31.4"

Real Distance = 97.4 m

Centroid = 43°28'03.5"
79°38'34.1"
@ 1338:15 Hrs.

$$\bar{x} = \frac{\sum_{i=1}^{m} c_i x_i}{\sum_{i=1}^{m} c_i} \text{ meters}$$

$$\bar{c} = \frac{\sum_{i=1}^{N} c_i}{N} \text{ ug/L}$$

c_i = Concentration of each element ug/L

x_i = Distance to centre of element m

N = Number of Elements

$$\sigma_x^2 = \frac{\sum_{i=1}^{m} c_i (x_i - \bar{x})^2}{\sum_{i=1}^{m} c_i} \text{ meters}^2$$

A1 - A2

$\bar{x}$ = 96.31 m

σ_x^2 = 2449.9 m²

B1 - B2

$\bar{x}$ = 55.03 m

σ_x^2 = 569.1 m²

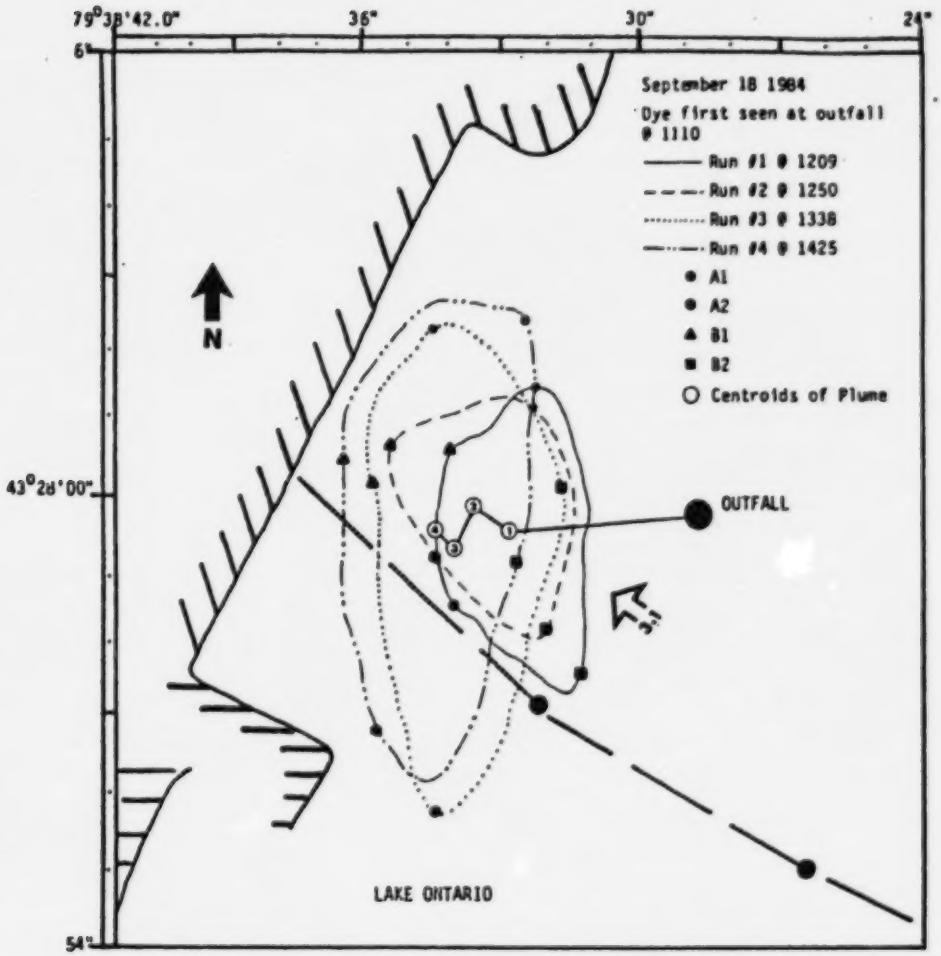
Overall Variance about centroid (σ_x^2) = 2515.2 m²

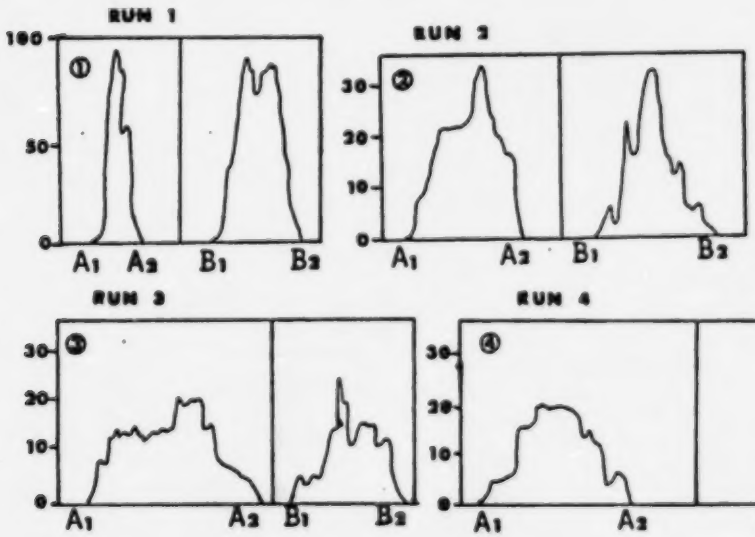
Standard Deviation (σ_x) = 50.2 m

Mean Concentration ($\bar{c}$) = 13.8 ug/L

FIGURE

OAKVILLE-FORD OUTFALL DYE INJECTIO
(September 18, 1984





Concentration in ug/l

3.1 Winds are in km

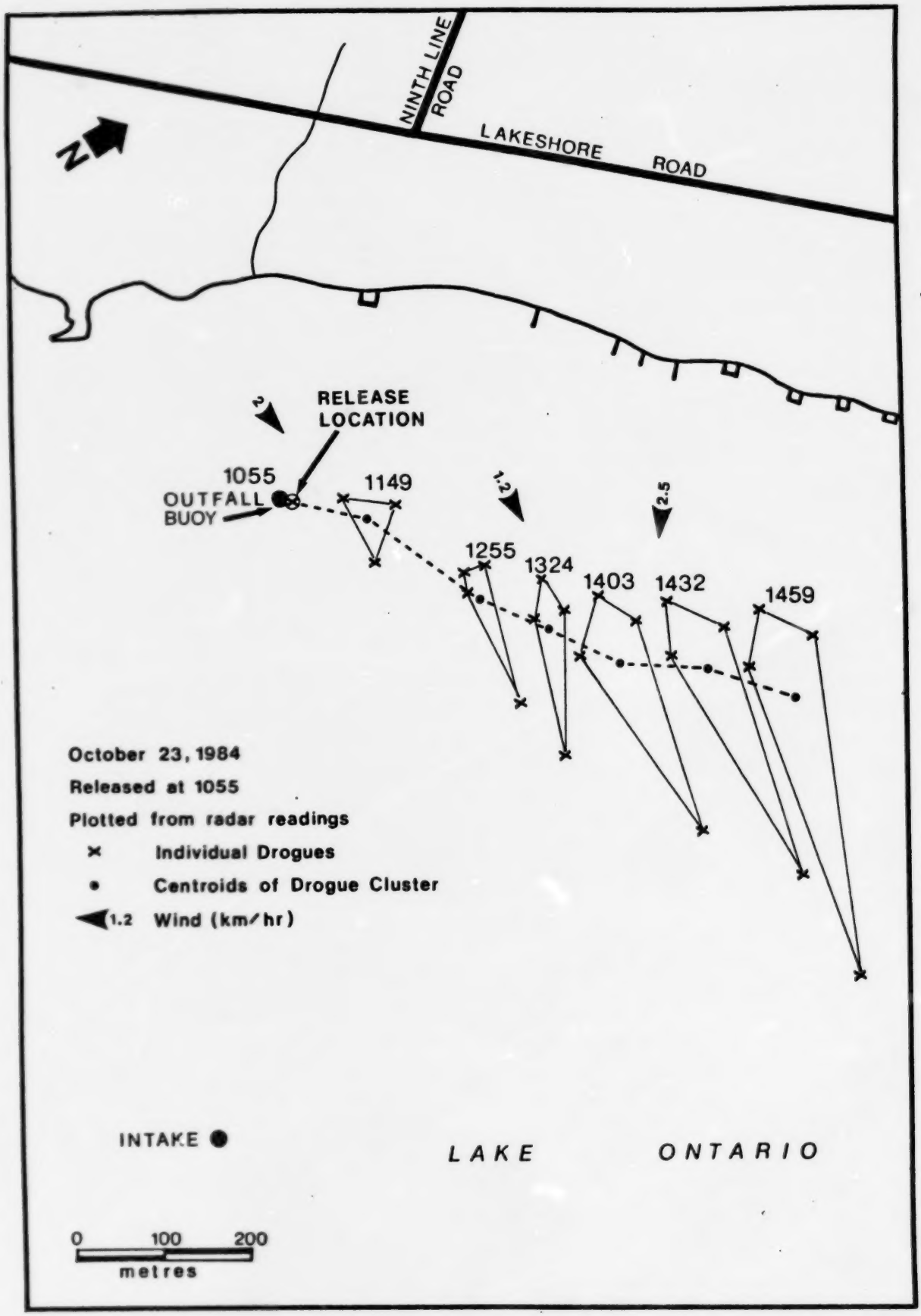


FIG. 5: OAKVILLE - FORD OUTFALL SAIL DROGUE TRACKING OCTOBER 23, 1984

FIGURE 6

LOCATION OF OAKVILLE - FORD OUTFALL AND LEAKS

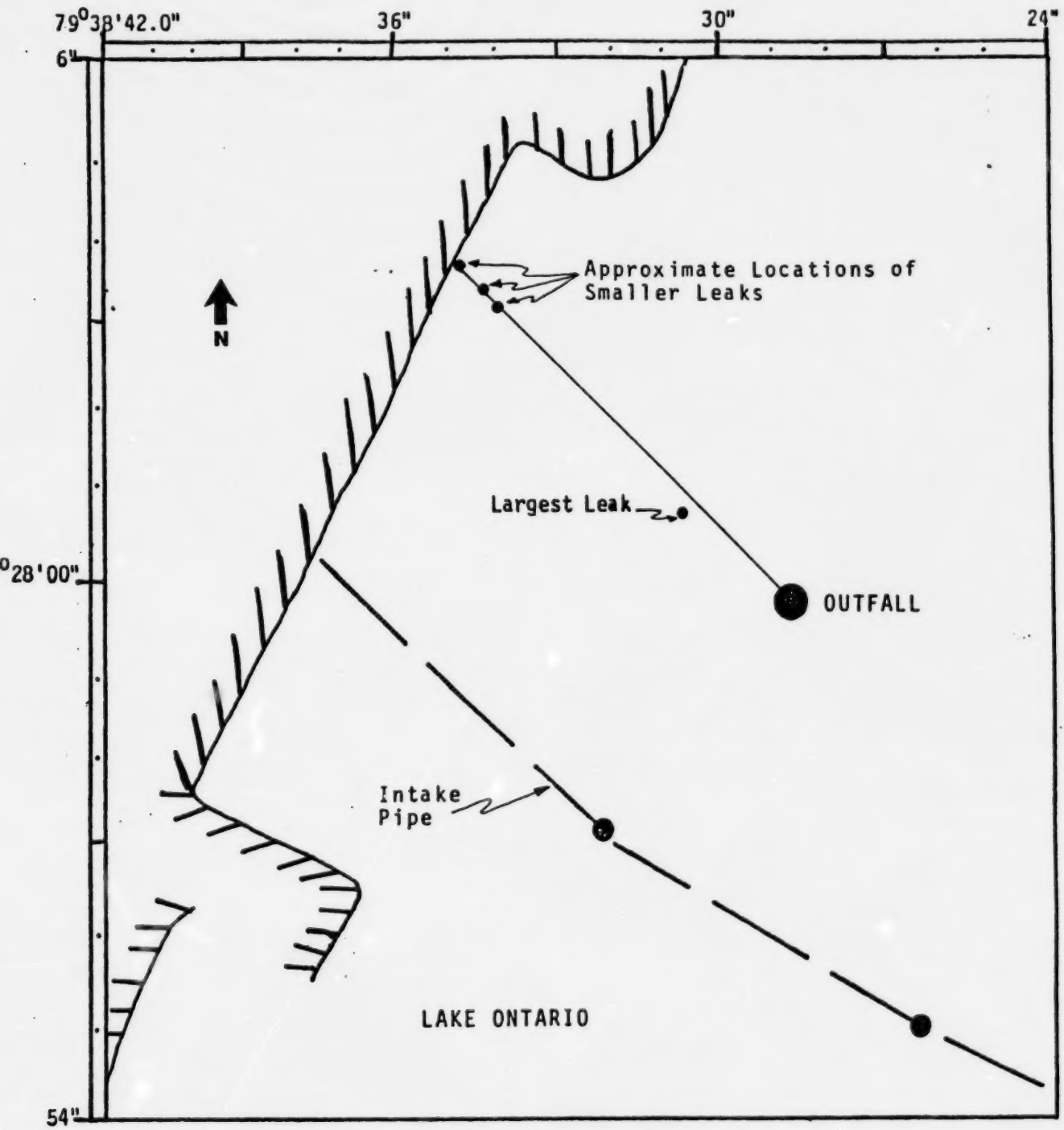


FIGURE 7

VARIANCE VS TIME (all data)

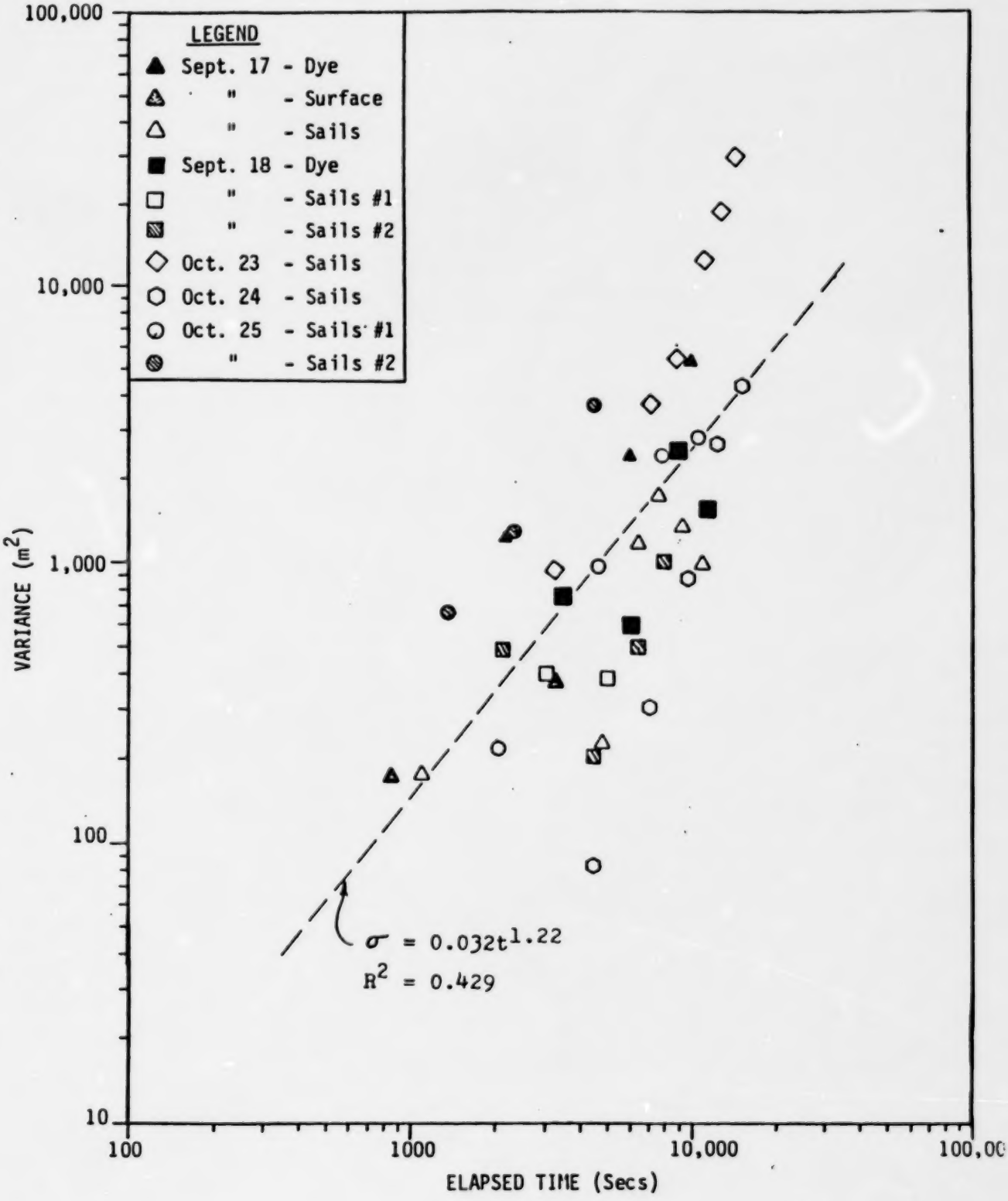


FIGURE 8

DILUTION RATIO VS DISTANCE

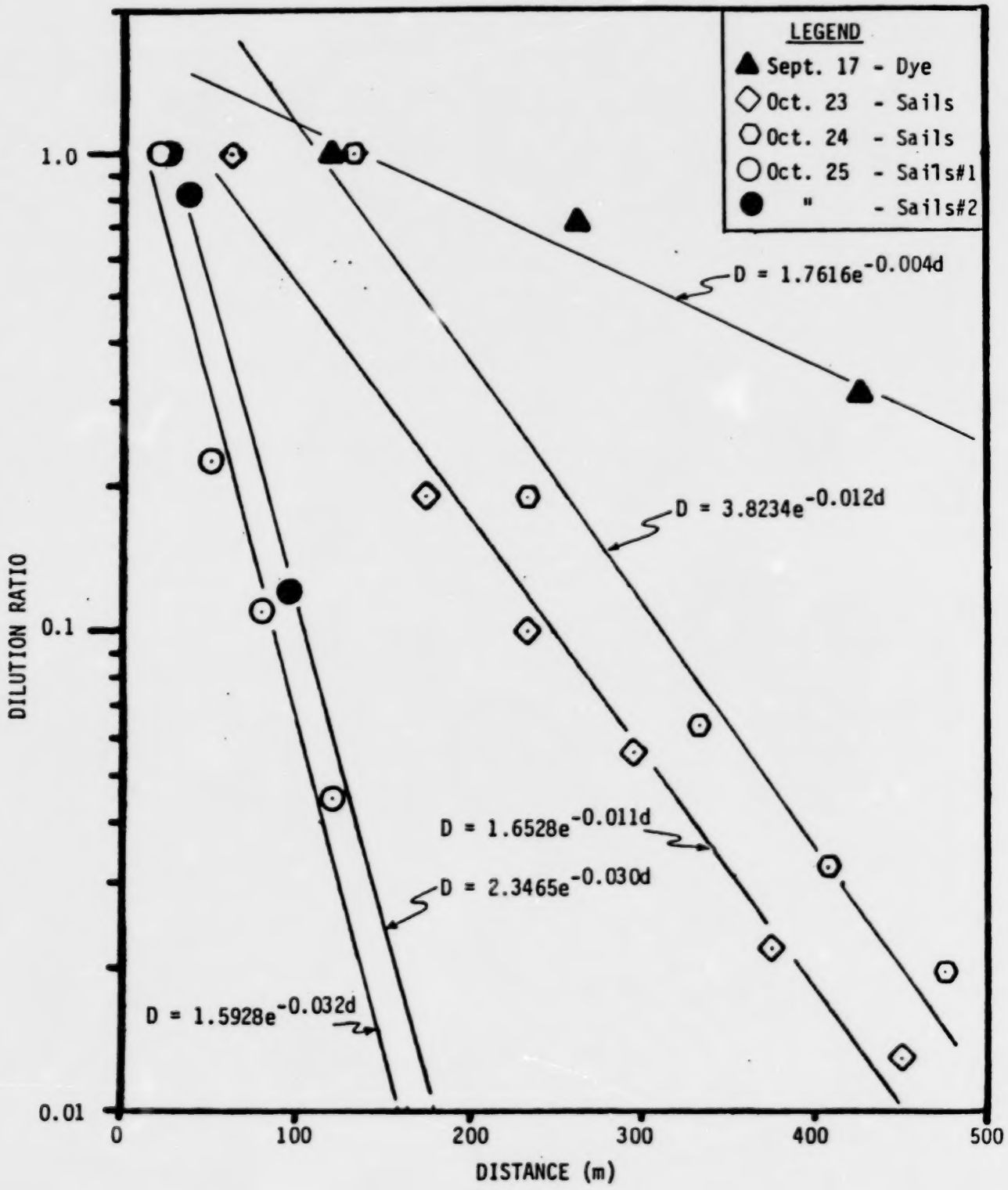


FIGURE 9

OAKVILLE-FORD OUTFALL 5:1 DILUTION CONTOURS

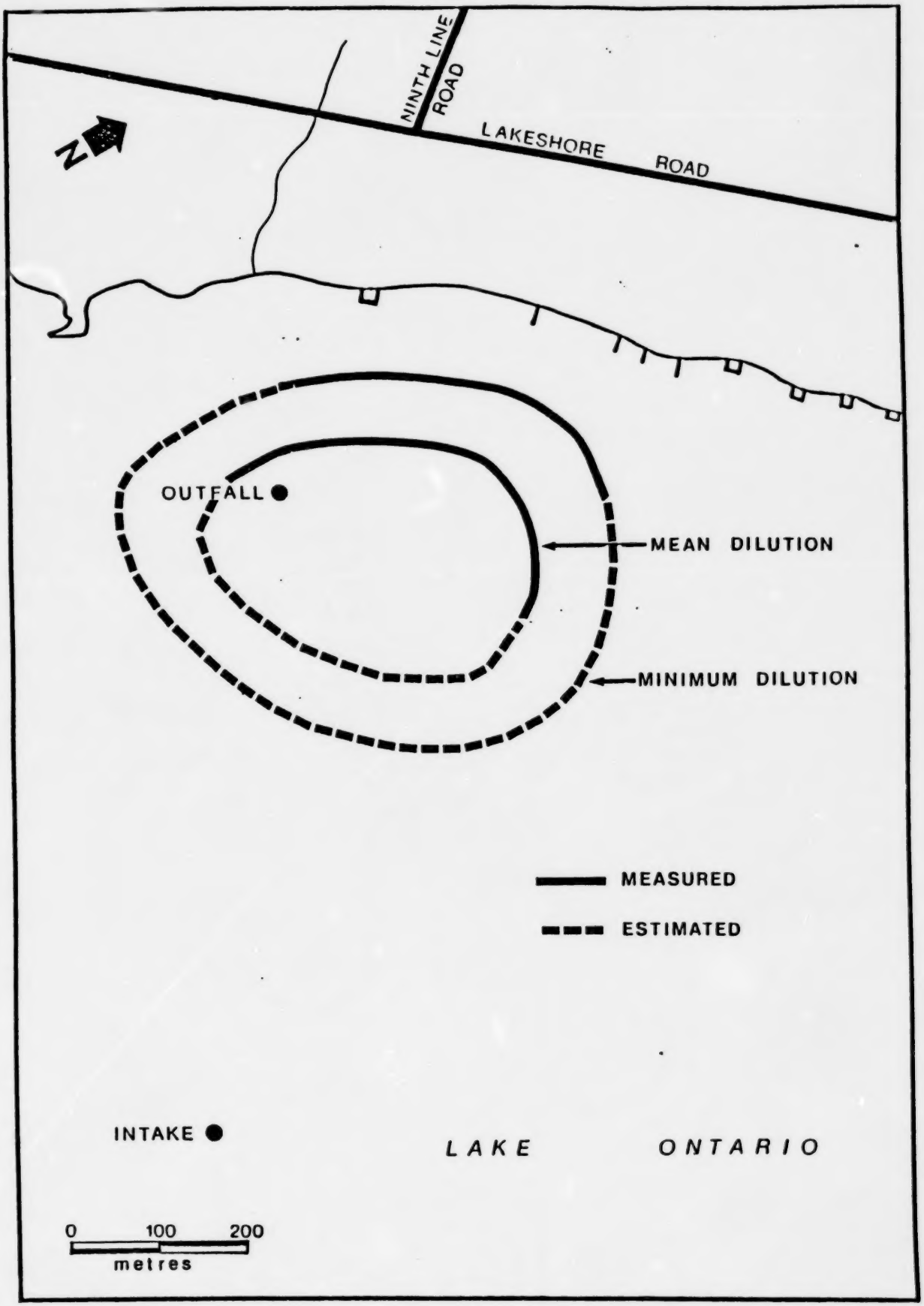


FIGURE 10

SAMPLE DISSOLVED OXYGEN - TEMPERATURE - DEPTH PROFILES
(October 23, 1984)

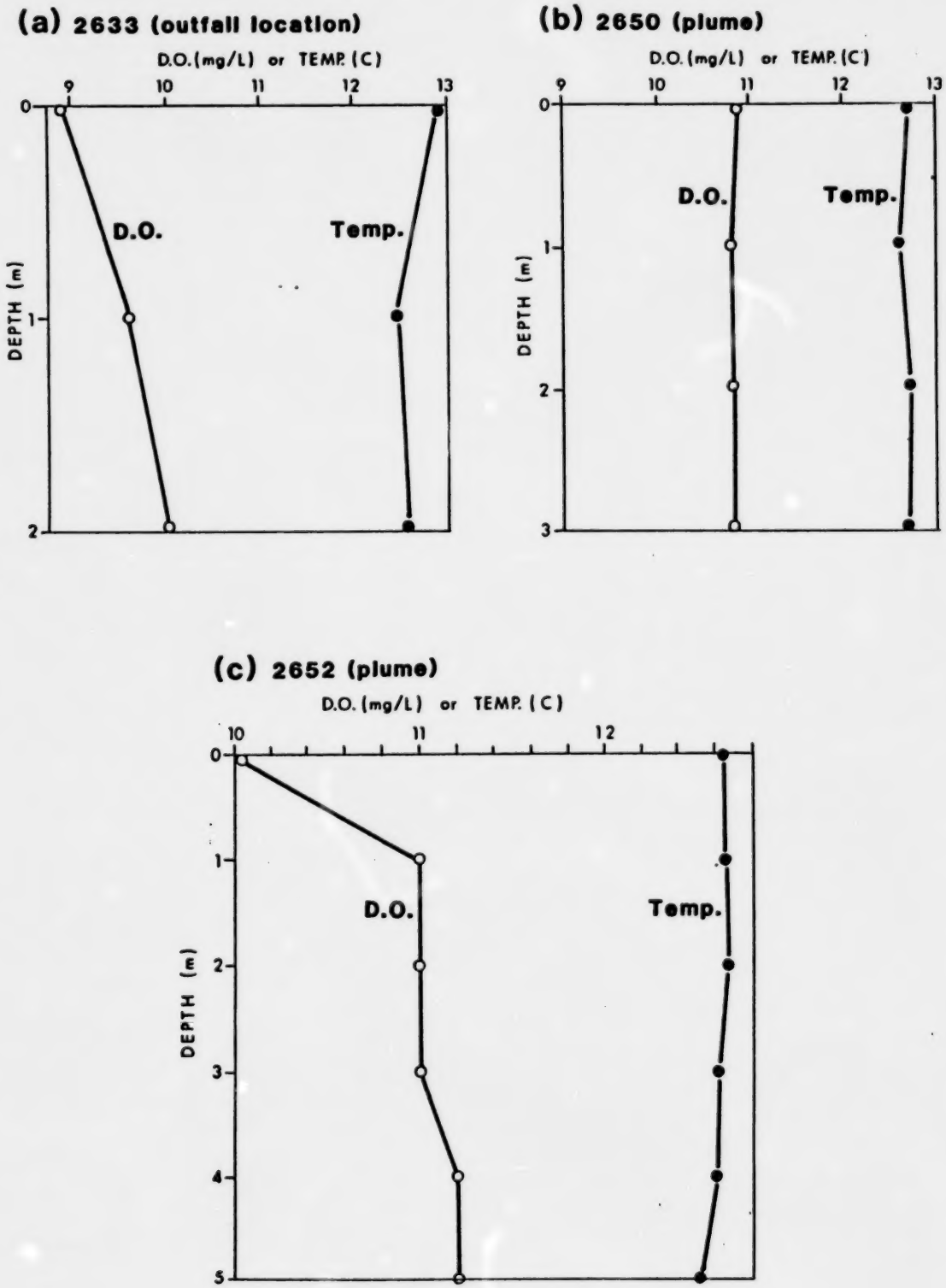


FIGURE 11a

EFFLUENT PLUME BOD CONCENTRATIONS
FORD-OAKVILLE (October 23, 1984)

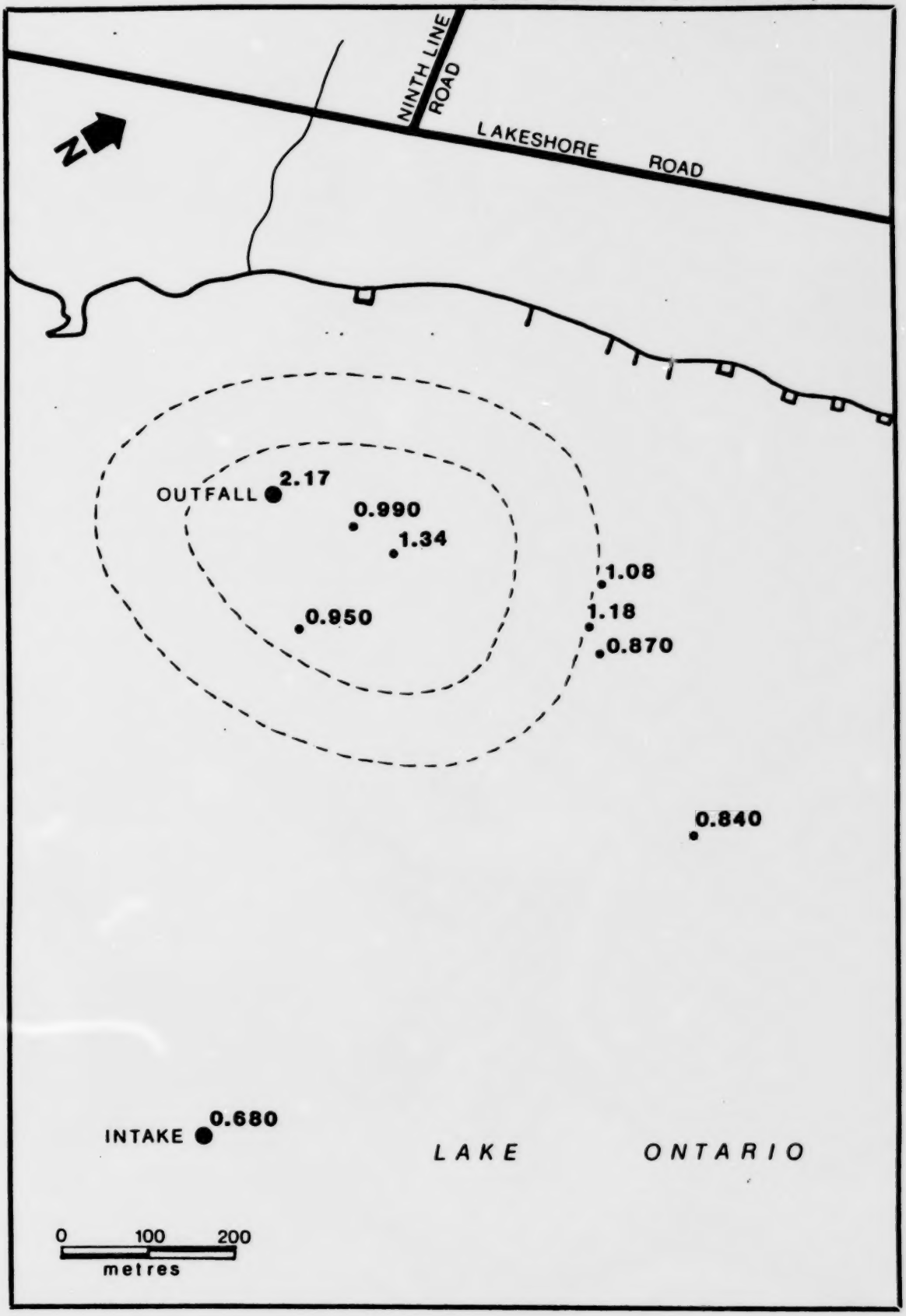


FIGURE 11b
EFFLUENT PLUME BOD CONCENTRATIONS
FORD-OAKVILLE (October 24, 1984

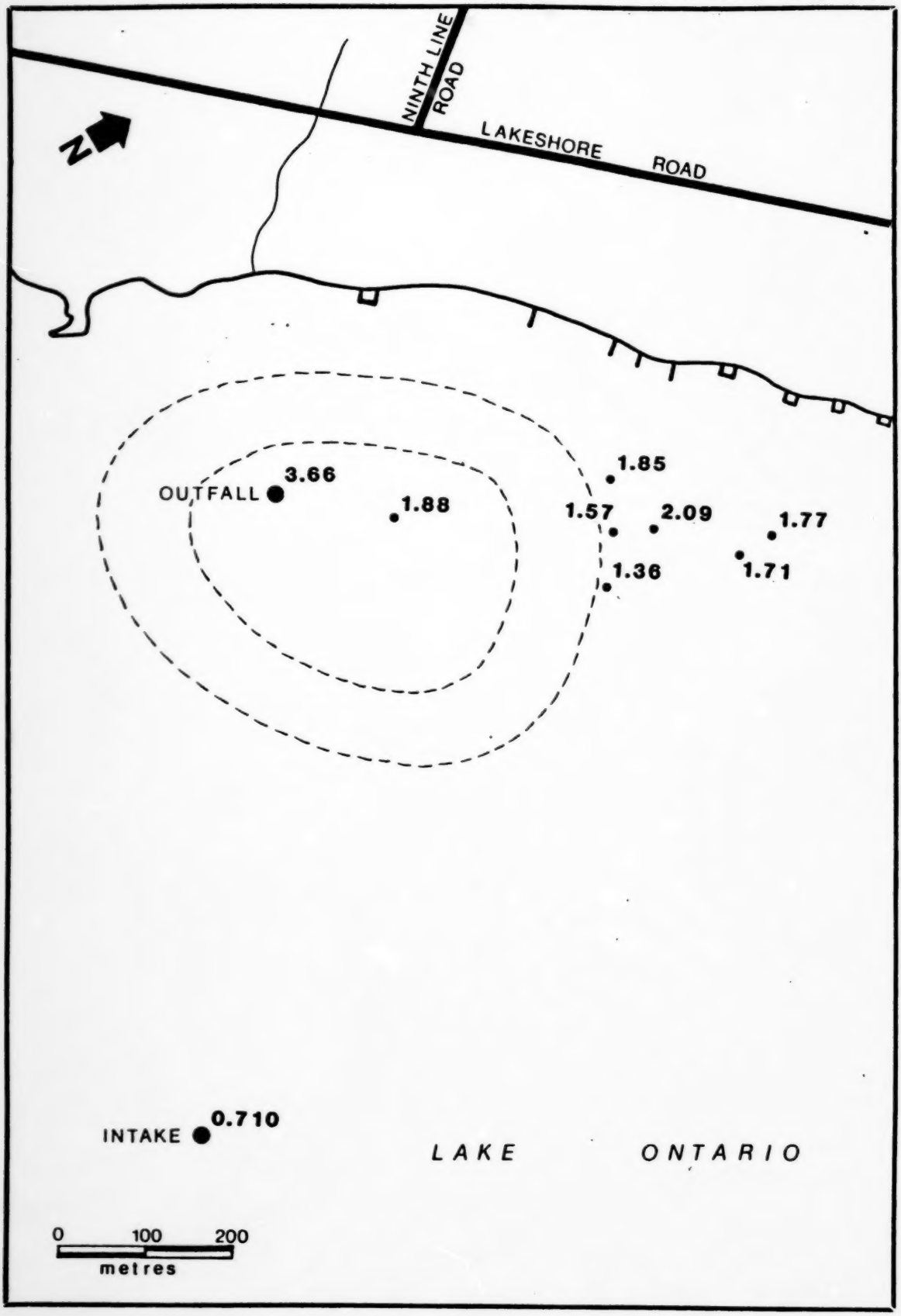


FIGURE 11c

EFFLUENT PLUME BOD CONCENTRATIONS
FORD-OAKVILLE (October 25, 1984)

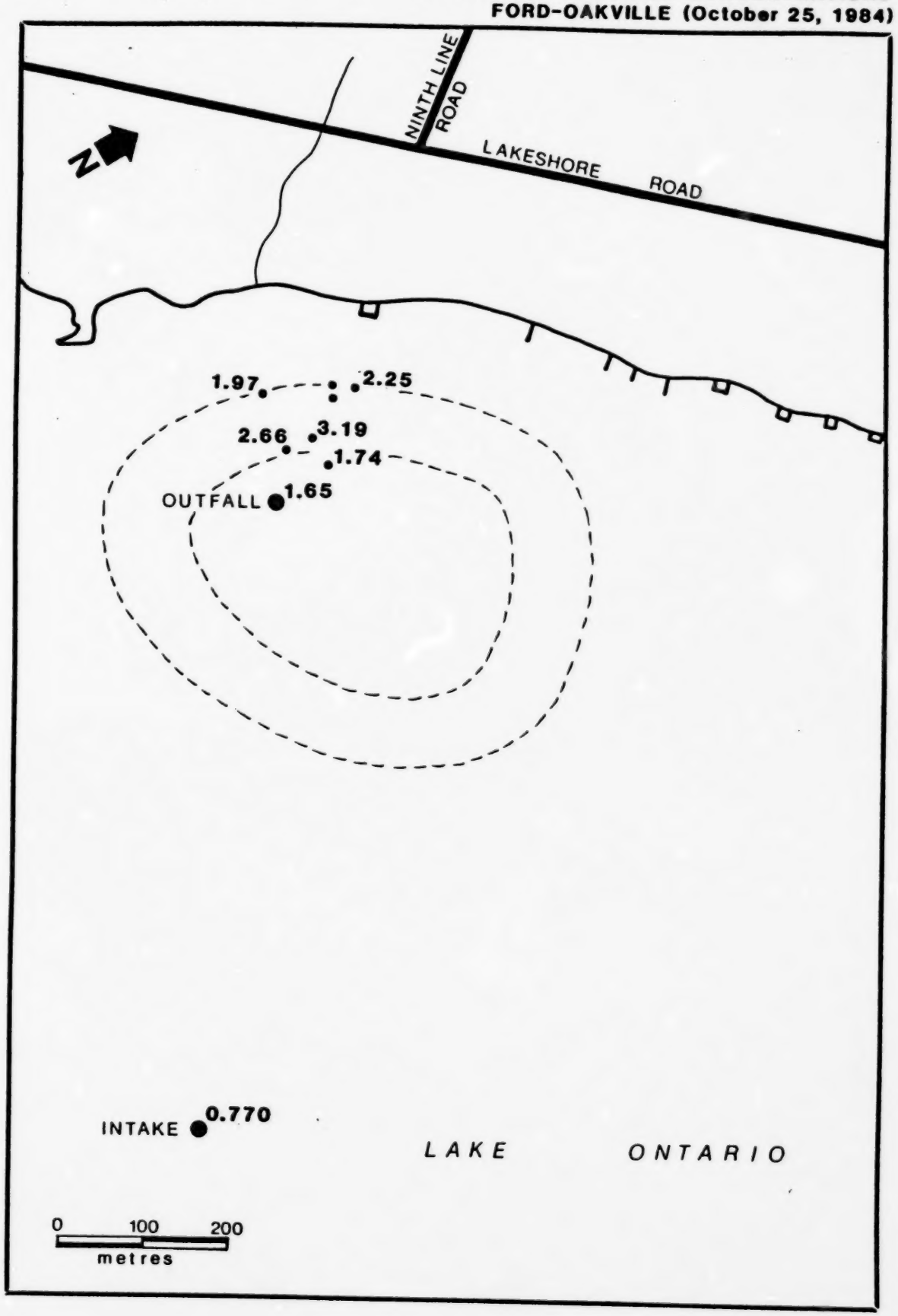
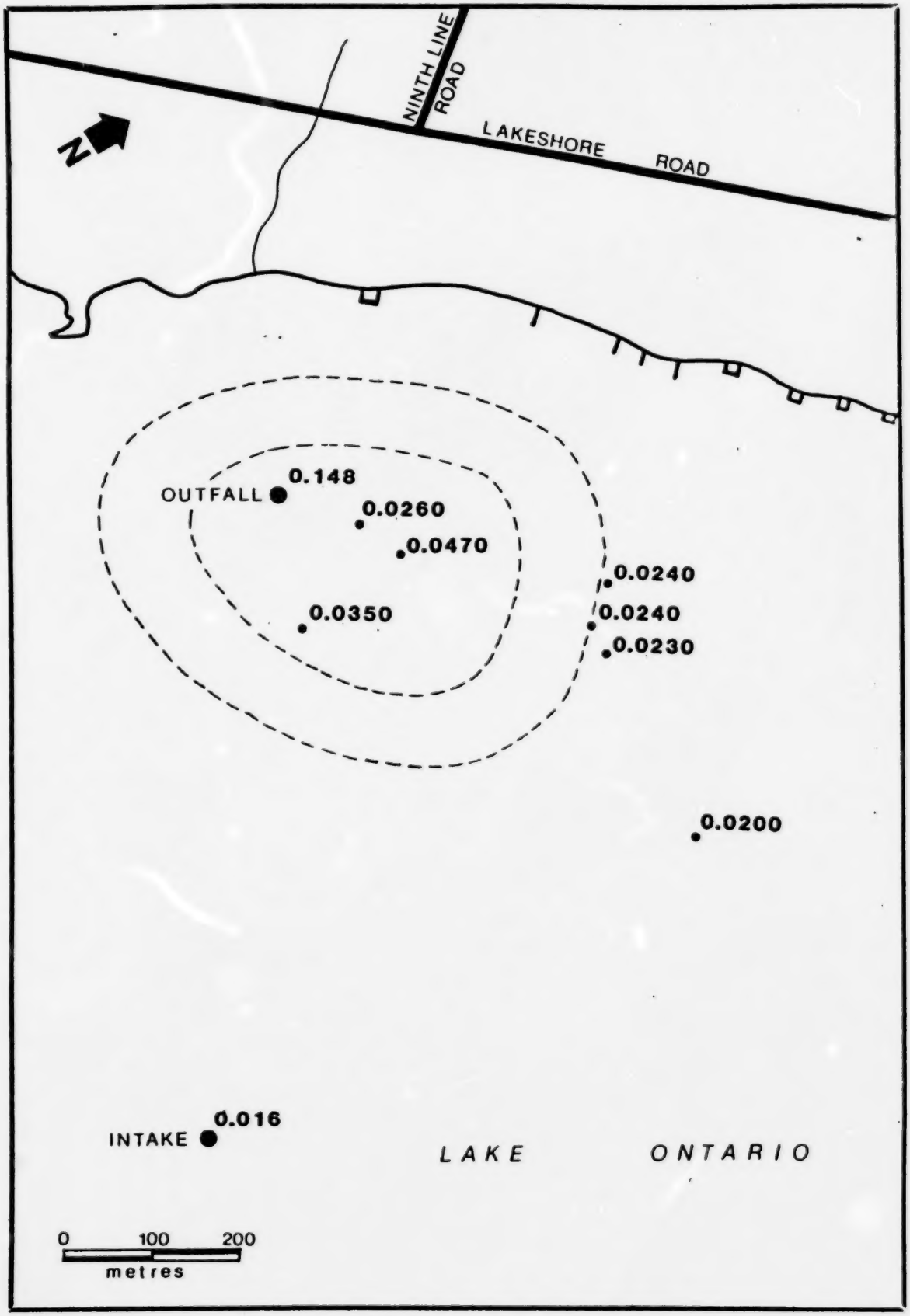


FIGURE 12a

EFFLUENT PLUME TOTAL P
FORD-OAKVILLE (October 23, 1984)



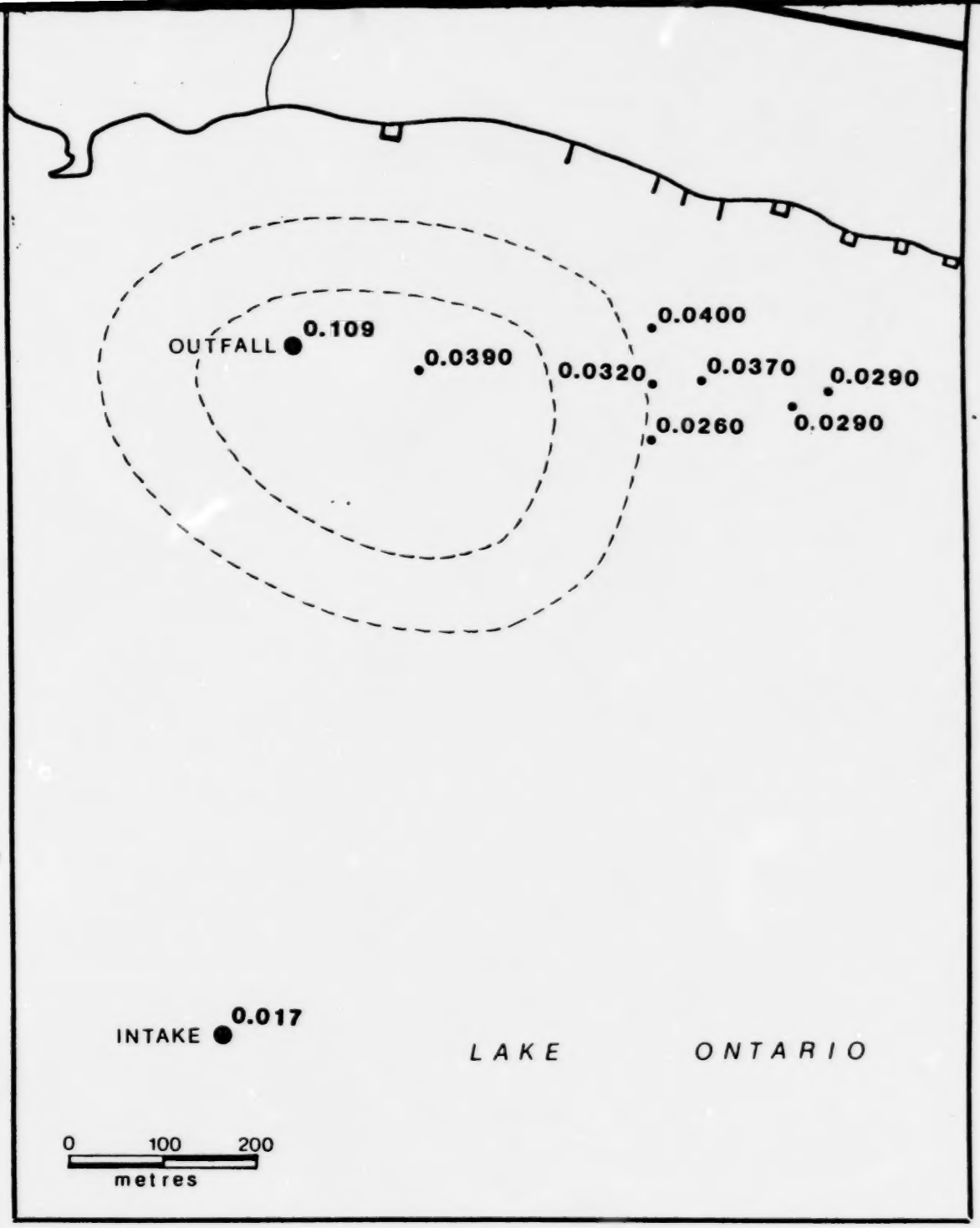
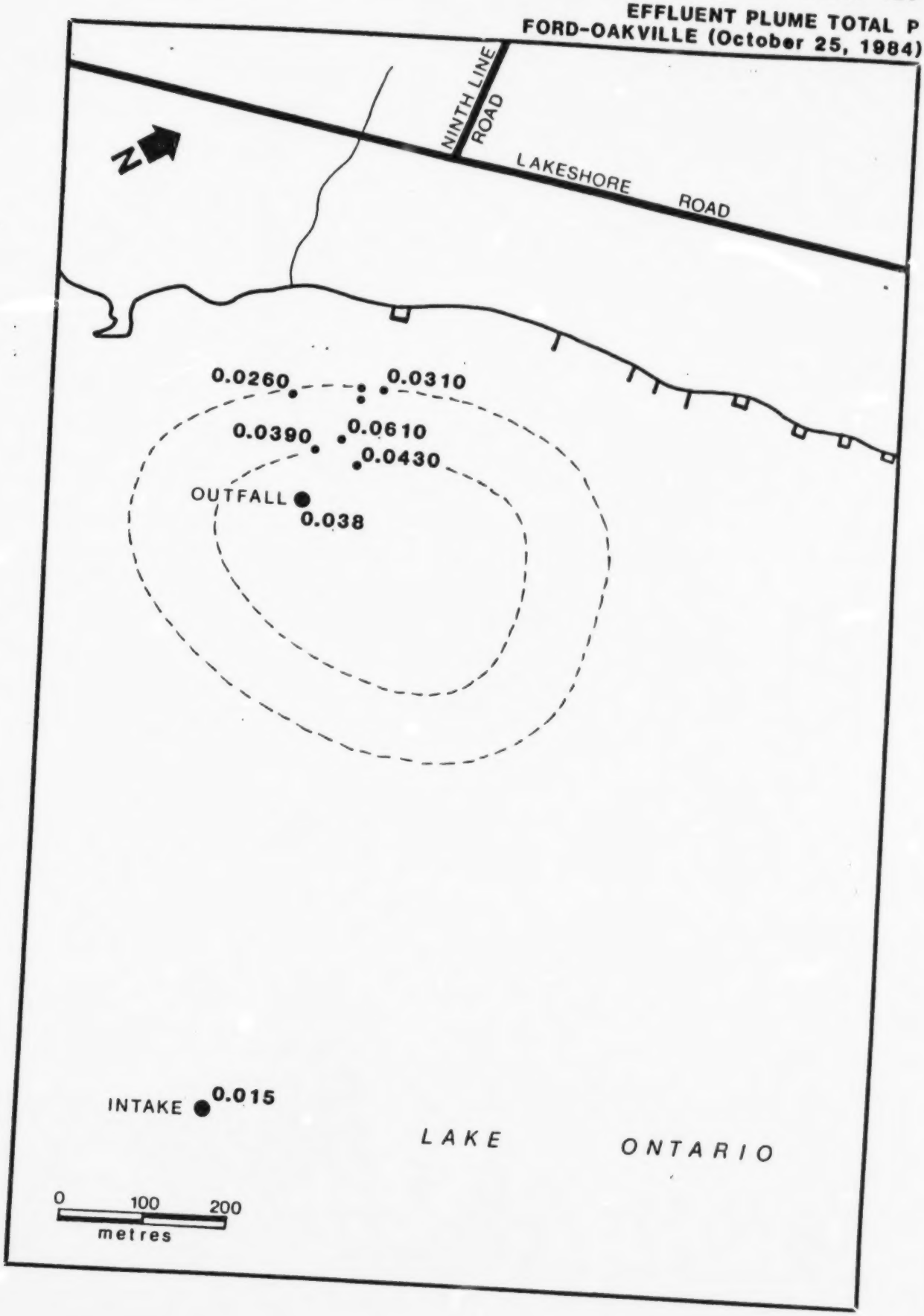

OUTFALL
0.109
0.0390
0.0320
0.0400
0.0370
0.0290
0.0260
0.0290
INTAKE
0.017
LAKE ONTARIO
0
100
200
metres

FIGURE 12c

EFFLUENT PLUME TOTAL P
FORD-OAKVILLE (October 25, 1984)



APPENDIX 1

Water Quality of Ford Effluent, Lake at outfall and intake buoys, and storm sewers and tributary mouths in immediate vicinity.

(a) Ammonia - N, mg/L as N

	Sep. 17	Sep. 18	Oct. 23	Oct. 24	Oct. 25	Mean	SD
Effluent -	.156	.110	.026	.380	.410		
-	.216	.014	.058	.034	.154	.187	.182
-	.514	.014	.504	.008	.214		
Outfall buoy-	.058	.252	.024	.044	.038	.083	.095
Intake buoy-	.044	.064	.028	.054	.052	.048	.013
Arbor Dr. SS-	.030	.062	.016	.002	.006	.023	.024
Maplegrove SS-	.010	.018	.016	.016	.002	.012	.007
Wedgewood CK-	.024	.020	.012	.014	.002	.014	.008
Cox Dr. SS-	.018	.224	.342	.032	.016	.126	.149
Morrison CK-	.034	.036	.020	.048	.008	.029	.015

(b) Total Kjeldahl Nitrogen, mg/L as N

	Sep. 17	Sep. 18	Oct. 23	Oct. 24	Oct. 25	Mean	SD
Effluent -	.870	1.38	1.80	1.58	9.10		
-	.870	1.12	1.10	1.50	1.02	1.221	.289
-	.930	1.32	1.53	1.27	1.17		
Outfall buoy-	.330	.490	.480	.530	.370	.440	.085
Intake buoy-	.270	.250	.300	.300	.300	.284	.023
Arbor Dr. SS-	.300	.320	.210	1.33	.201	.472	.482
Maplegrove SS-	.270	.220	.320	.280	.230	.264	.040
Wedgewood CK-	.450	.500	.310	.430	.290	.396	.091
Cox Dr. SS-	.390	1.72	7.10	.460	.270	1.988	2.91
Morrison CK-	.800	.370	.380	.360	.310	.444	.201

APPENDIX 1 - continued

(c) Total Phosphorus, mg/L as P

	Sep. 17	Sep. 18	Oct. 23	Oct. 24	Oct. 25	Mean	SD
Effluent -	.408	.550	.815	.645	.310		
-	.295	.440	.625	.605	.675	.513	.172
-	.228	.453	.340	.625	.675		
Outfall buoy-	.027	.082	.148	.109	.038	.0808	.050
Intake buoy-	.013	.011	.016	.017	.015	.014	.002
Arbor Dr. SS-	.020	.028	.012	.019	.011	.018	.007
Maplegrove SS-	.008	.024	.028	.030	.027	.023	.009
Wedgewood CK-	.023	.054	.018	.045	.038	.0356	.015
Cox Dr. SS-	.268	1.10	6.40	.580	.550	1.78	2.60
Morrison CK-	.039	.034	.042	.041	.022	.0356	.008

(d) Conductivity, umho/cm

	Sep. 17	Sep. 18	Oct. 23	Oct. 24	Oct. 25	Mean	SD
Effluent -	485	410	510	500	387		
-	430	450	440	555	500	463.13	48.9
-	390	445	450	475	520		
Outfall buoy-	325	390	350	342	325	346.4	26.7
Intake buoy-	320	320	325	318	320	320.6	2.60
Arbor Dr. SS-	815	825	645	790	645	744	91.3
Maplegrove SS-	1,090	1,080	1,070	1,090	1,090	1,084	8.94
Wedgewood CK-	1,220	880	750	720	563	826.6	247.1
Cox Dr. SS-	990	815	980	1,000	1,000	957	79.8
Morrison CK-	750	705	590	565	805	683	102.99

APPENDIX 1 - continued

(e) Turbidity, FTU

	Sep. 17	Sep. 18	Oct. 23	Oct. 24	Oct. 25	Mean	SD
Effluent -	5.40	5.10	7.60	11.6	2.70		
-	4.70	18.6	73.0	12.5	11.3	12.7	17.2
-	3.20	11.9	7.70	6.30	7.40		
Outfall buoy-	1.66	43.0	1.55	1.08	1.07	9.67	18.6
Intake buoy-	3.50	2.30	1.86	1.17	1.11	1.988	.980
Arbor Dr. SS-	1.45	2.40	1.34	1.15	.320	1.33	.744
Maplegrove SS-	4.30	1.70	1.01	1.68	.740	1.886	1.41
Wedgewood CK-	3.50	6.80	2.10	5.10	2.70	4.04	1.90
Cox Dr. SS-	.580	14.2	64.0	.460	.470	15.9	27.5
Morrison CK-	4.60	5.20	3.20	2.80	2.20	3.6	1.26

(f) BOD, mg/L

	Sep. 17	Sep. 18	Oct. 23	Oct. 24	Oct. 25	Mean	SD
Effluent -	2.24	4.56	31.1	44.1	2.72		
-	2.04	32.7	9.84	47.2	34.5	22.5	18.9
-	.660	29.8	5.16	46.1	44.8		
Outfall buoy-	.510	7.48	2.17	3.66	1.65	3.09	2.70
Intake buoy-	.380	.800	.680	.710	.770	.668	.168
Arbor Dr. SS-	.030	.280	.240	.340	.230	.224	.117
Maplegrove SS-	.120	.230	1.29	.410	.450	.5	.462
Wedgewood CK-	.160	.310	.770	1.16	.800	.64	.404
Cox Dr. SS-	.110	12.9	90.4	.520	.470	20.9	39.2
Morrison CK-	.190	.280	.820	.950	.760	.6	.342

APPENDIX 1 - continued

(g) Copper, mg/L (unfiltered)

	Sep. 17	Sep. 18	Oct. 23	Oct. 24	Oct. 25	Mean	SD
Effluent -	.047	.038	.041	.032	.026		
-	.028	.030	.038	.041	.033	.0348	.006
-	.026	.040	.036	.034	.032		
Outfall buoy-	.004	.032	.007	.008	.003	.0108	.012
Intake buoy-	.003	.003	.003	.003	.003	.003	0

(h) Chromium, mg/L (unfiltered)

	Sep. 17	Sep. 18	Oct. 23	Oct. 24	Oct. 25	Mean	SD
Effluent -	.016	.035	.083	.086	.007		
-	.020	.045	.049	.120	.100	.057	.040
-	.002	.044	.028	.110	.110		
Outfall buoy-	.003	.025	.010	.018	.004	.012	.009
Intake buoy-	.002	.002	.002	.003	.002	.0022	.0004

(i) Iron, mg/L (unfiltered)

	Sep. 17	Sep. 18	Oct. 23	Oct. 24	Oct. 25	Mean	SD
Effluent -	-	.100	.270	.110	.072		
-	-	.110	.190	.220	.290	.1885	.0936
-	-	.140	.360	.120	.280		
Outfall buoy-	-	-	.048	.035	.024	.0356	.012
Intake buoy-	-	-	.029	.025	.019	.024	.005

(j) Nickel, mg/L (unfiltered)

	Sep. 17	Sep. 18	Oct. 23	Oct. 24	Oct. 25	Mean	SD
Effluent -	.017	.096	.160	.150	.030		
-	.030	.120	.095	.190	.091	0.097	0.056
-	.005	.120	.110	.150	.099		
Outfall buoy-	.002	.060	.021	.026	.003	.022	.024
Intake buoy-	.001	.001	.001	.001	.001	.001	0

Outfall buoy-	<.003	<.003	<.003	<.003	<.003	<.003	-
Intake buoy-	<.003	<.003	<.003	<.003	<.003	<.003	-

(l) Zinc, mg/L (unfiltered)

	Sep. 17	Sep. 18	Oct. 23	Oct. 24	Oct. 25	Mean	SD
Effluent -	.017	.069	.150	.055	.017		
-	.031	.087	.085	.076	.064	.063	.036
-	.010	.085	.079	.051	.064		
Outfall buoy-	.013	.041	.015	.010	.003	.016	.014
Intake buoy-	.001	.002	.002	.003	.002	.002	.0007

(m) Phenolics, ug/L

	Sep. 17	Sep. 18	Oct. 23	Oct. 24	Oct. 25	Mean	SD
Effluent -	1.60	3.60	4.00	3.80	2.60		
-	1.00	5.20	2.60	13.4	3.80	4.11	3.06
-	<.200	5.00	6.60	4.40	3.80		
Outfall buoy-	BD	1.60	1.20	<.40	<.20	<1	-
Intake buoy-	-	1.00	BD	BD	BD	<1	-

Note: BD = below detection

(n) Solvent Extractables, mg/L

	Sep. 17	Sep. 18	Oct. 23	Oct. 24	Oct. 25	Mean	SD
Effluent -	0	1	2	0	3		
-	2	1	1	1	4	1.8	1.1
-	1	1	1	0	3		
Outfall buoy-	2	1	1	0	0	<1	-
Intake buoy-	1	0	0	0	0	<1	-

APPENDIX 2

Data Analysis Procedures

1. Dye Tracking

Computation of the centroid and variance of the dye plume is illustrated using the fluorometer trace (Figure 3) of run #3 on September 18, 1984 (Figure 4). Points A1, A2, B1 and B2 represent the edges of the dye patch (circled points on Figure 4). The fluorometer trace is divided into equal elements as in Figure 3. These represent equal distance increments if the boat has traversed the plume at a constant speed. If c_i = dye concentration in each element and X_i = distance of center of element from point A1, the location of the center of mass along the axis A1-A2 is given by

$$\bar{x} = \frac{\sum_{i=1}^{N} C_i X_i}{\sum_{i=1}^{N} C_i} \quad (m)$$

where N = number of elements.

Average concentration $\bar{c}$ is given by

$$\bar{c} = \frac{\sum_{i=1}^{N} C_i}{N} \quad (ug/L)$$

Computation of the centroid and variance of the dye plume is illustrated using the fluorometer trace (Figure 3) of run #3 on September 18, 1984 (Figure 4). Points A1, A2, B1 and B2 represent the edges of the dye patch (circled points on Figure 4). The fluorometer trace is divided into equal elements as in Figure 3. These represent equal distance increments if the boat has traversed the plume at a constant speed. If c_i = dye concentration in each element and X_i = distance of center of element from point A1, the location of the center of mass along the axis A1-A2 is given by

$$\bar{x} = \frac{\sum_{i=1}^{N} C_i X_i}{\sum_{i=1}^{N} C_i} \quad (m)$$

where N = number of elements.

Average concentration $\bar{c}$ is given by

$$\bar{c} = \frac{\sum_{i=1}^{N} C_i}{N} \quad (ug/L)$$

This relation is used to quantify the dilution ratio $c(X_1)/c(X_2)$ between two locations, X_1 and X_2, as follows

$$\frac{C(X_1)}{C(X_2)} = \frac{\sigma_2^2 V_2}{\sigma_1^2 V_1}$$

2. Drogue Tracking

At each time interval, the centroid of the drogue cluster is determined by averaging the latitudes and longitudes of the individual drogues. The variance of the drogues about the centroid is then calculated, and the dispersion and dilution functions are calculated in the same manner as used for dye studies.

/rmg
00497-06A